JINA-CEE

Center for the Evolution of the Elements

January 2016

A note from the Director, Hendrik Schatz

Happy new year and welcome to the first newsletter after our successful renewal as JINA Center for the Evolution of the Elements (JINA-CEE). With JINA-CEE, JINA continues its growth as a multi-national, and interdisciplinary research center with a number of new members and participants. Our goals are to continue to advance our understanding of the Origin of the Elements (Major Activity 1) and the Dense Matter in Neutron Stars (Major Activity 2), provide a stimulating environment for young scientists, and serve as a center for the broader field that continues to forge connections between the diverse communities that constitute nuclear astrophysics.

A key for our success in realizing our vision for JINA-CEE will be continued communication across the center, including the new participants, to trigger new ideas and collaborations and to enable coordination. In this context I am particularly thrilled to welcome Lena Simon, who started in October 2014 as managing director. She will manage scientific communication and coordination within the center, and with the broader nuclear astrophysics community. You can find more information about Lena and her position in this newsletter. I would like to encourage you to contact her with questions and ideas.

Workshops are an important element of JINA-CEE, and I would like to direct your attention of the large number of planned workshops in Spring and Summer 2016 (see jinaweb.org). Among many others, this includes two important larger workshops that cover each of the JINA-CEE Major Activities - "Neutron Stars in the Multi messenger Era", May 23-27 at Ohio University, and "From Nuclei to the Cosmic Web", July 10-14, at MSU. I also hope to see all of you at the upcoming JINA-CEE Frontiers Meeting at the University of Notre Dame, March 29-31, which serves as our annual open collaboration meeting. This will be an excellent opportunity for students and postdocs to present their research and for all of us to discuss new initiatives, identify synergistic connections between projects, and plan for the coming years.

Again, I wish you all a successful new year with lots of exciting scientific discoveries!

Inside this issue

New faces: Lena Simon, JINA-CEE Managing Director

Hi! I am Lena, the new JINA-CEE Managing Director. After obtaining my PhD in theoretical quantum optics at Dresden University of Technology in Germany, I am rather new in the field of Nuclear Astrophysics. However, Astrophysics nudged me to study physics in the first place and, therefore, I am very excited about my new job in this interdisciplinary, frontier-crossing and fascinating area of research.

In my new job, I will be responsible to manage the scientific communication and coordination within JINA-CEE. I will support conference planning, take care of our website and the newsletter, as well as help with any activity or event that can foster collaboration.

Moreover, my scope of activities covers the external scientific communication as well. I will give my best to inform the broader public about our fascinating research , for example on our JINA-CEE Twitter account.

So, if you want to share new highlights, news, publications, events, or anything else that could contribute to the communication within our center, please don't hesitate to contact me! In the meanwhile, I am looking forward to meeting some of you at the next Frontiers Meeting in ND!

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TRIUMF

CNA

New International Partners with JINA-CEE

JINA-CEE has two new partners in its effort to foster scientific collaboration across nuclear astrophysics at institutions around the world. Recently, memoranda of understanding (MOU) were signed with TRIUMF in Vancouver, Canada, and Shanghai Jiao Tong University in Shanghai, China.

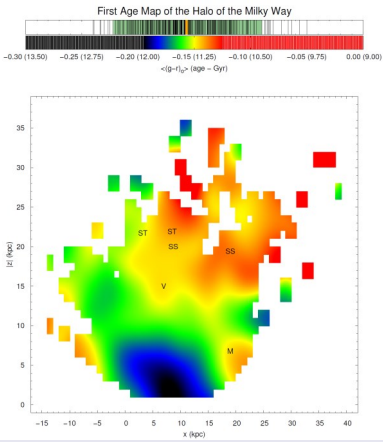
TRIUMF, Canada's National Laboratory for Nuclear and Particle Physics in Vancouver, Canada operates one of the leading ISOL RIB facilities and collaboration will focus on joint experiments and equipment development, cross disciplinary training, and linking experiments with astrophysical models. New JINA-CEE senior collaborators from TRIUMF are Barry Davids, Iris Dillmann, Reiner Kruecken, and Chris Ruiz.

Shanghai Jiao Tong University is the site of the newly founded "Center for Nuclear Astrophysics (CNA)". CNA and JINA-CEE will collaborate on experimental and theoretical research in nuclear astrophysics and will cooperate on training young scientists, for example through the newly established "Young Scientist Study Group". New JINA-CEE senior collaborators from CNA Yang Sun, Yong-Zhong Qian, Lie-Wen Chen, Yu-Min Zhao and Chang-Bo Fu.

JINA-CEE Collaboration Produces First Age Map of Galactic Halo

Contributed by Timothy Beers, University of Notre Dame

The assembly history of the Milky Way provides fundamental information not only on the growth of large galaxies throughout the Universe, but helps to constrain the nature of the stellar populations that are found throughout the halo of the Galaxy. JINA-CEE researchers have now used a technique originally developed in part by Notre Dame Chair of Astrophysics Timothy Beers, which maps the colors of core-helium burning stars, known as Blue Horizontal-Branch (BHB) stars, into estimates of stellar ages, and used these to produce the first chronographic (age) map of the Milky Way's halo population. Extensions of this technique are now being used to produce an even higher resolution age map based on large photometric samples of stars from the Sloan Digital Sky Survey, and even larger samples that are coming available in the near future.



Distribution of star ages in our Galaxy's halo.

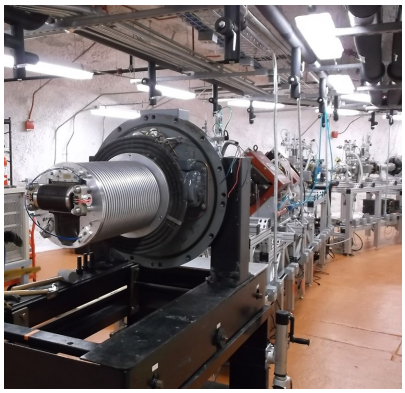
The map shows the distribution of derived ages for stars in the halo of our galaxy, the Milky Way. The team producing this map was led by JINA-CEE researchers Beers, along with Notre Dame Research Professors Vinicius Placco and Daniela Carollo. The map demonstrates that some of the oldest stars in the Galaxy, shown in black/blue at the bottom, are found close to the Galactic Center (X=0, |Z| = 0 in the map), as predicted by contemporary models for galaxy assembly, and that this Ancient Chronographic Sphere extends out to our Sun's location (X = 8.5, |Z| = 0), indicating that many old metal-poor stars can be found relatively nearby.

The capital letters mark the positions of known over-densities and stellar debris streams from accreted smaller galaxies. Details are available in the published work: C*hronography of the Milky Way's Halo System with Field Blue Horizontal-Branch Stars*, Santucci, R., et al.,APJ **813**, 16 (2015).

CASPAR accelerator assembled underground

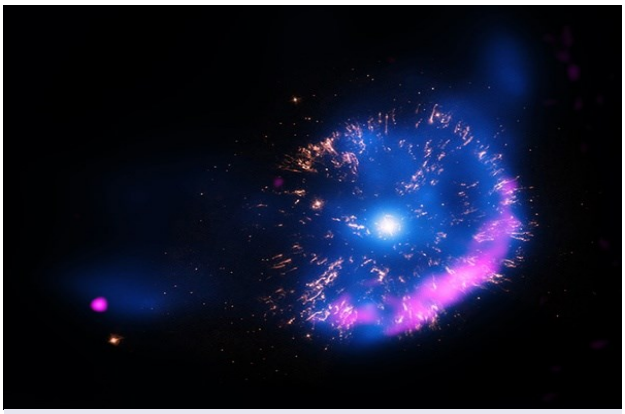
Contributed by Michael Wiescher, University of Notre Dame

Over two years in the making, this January the CASPAR (Compact Accelerator System for Performing Astrophysical Research) facility reached a long anticipated milestone with the installation of the 1 MV accelerator column. This final equipment placement completes the first stage of installation at the Sanford Underground Research Facility (SURF). The complexities of creating a nuclear astrophysics lab a mile underground have presented many unique challenges along the way. Equipment designed, built and tested at the University of Notre Dame was deconstructed into modular components, ready for underground installation at a repurposed gold mine 4850 feet below Lead, South Dakota. With these sections now reassembled, a final push is underway towards full system commissioning prior to the projected start of beam tests in the spring. Accelerator operations will make CASAPR the deepest underground accelerator facility in the world and the first of its kind in the US. With the great strides being made by the CASPAR team, full operation of the system will soon lead to reaction measurements significant for neutron sources for the s-process.



Weak-rate Library for Astrophysical Simulations

Contributed by Remco Zegers, Michigan State University



Nova GK Persei. Image credit: X-ray: NASA/CXC/RIKEN/D. Takei et al; Optical: NASA/STScI; Radio: NRAO/VLA

Modelling the collapse of massive stars and their explosive demise as supernovae is a scientific challenge. Despite major collaborative efforts by researchers across diverse fields, there are still many open questions related to core-collapse supernovae. It is not well understood how the collapse evolves into the explosion and how supernovae contribute to the synthesis of elements and the chemical evolution of the galaxy.

To make progress in understanding core-collapse supernovae, a close collaboration between astrophysical observers, modelers, nuclear theorists, and experimentalists is required. Simulating the evolution of the star in its final stages, requires that modelers use accurate nuclear physics inputs. Electron-capture reactions on medium-heavy nuclei, which are mediated by the weak nuclear force, play an important role in the dynamical evolution of the collapse of a massive star and the development of the shockwave that initiates the explosion.

Electron-capture reaction-rates on hundreds of nuclei must be known for accurate simulations. Direct measurements of these rates under hot and dense stellar conditions is impossible, but they can be derived from so-called data obtained from experiments that utilize charge-exchange reactions. Charge-exchange experiments are only possible for a limited set of nuclei, but they serve to benchmark and guide the development of state-of-the-art theoretical calculations, which can then be used to estimate the electron-capture rates for many other nuclei.

The charge-exchange group led by JINA-CEE senior investigator Remco Zegers at NSCL performs charge-exchange experiments and collaborates intensively with nuclear theorists to validate relevant theoretical calculations. These combined efforts have led to the creation of a library of weak reaction rates, which can be used by astrophysicists in their simulations. The library, which combines various sets of electron-capture rates based on different theoretical approaches that are benchmarked by experiment, was built by NSCL graduate student Chris Sullivan and integrated into the neutrino-interaction library NuLib, developed by Evan O'Connor (NSCU).

In close collaboration with Evan O'Connor, Chris used the library in a study aimed at testing the sensitivity of the evolution of core-collapse supernovae to uncertainties in the electron-capture rates. This sensitivity study was performed in a one-dimensional simulation of the collapsing star using the code GR1D. The simulations are important for understanding the uncertainties in the evolution of supernovae due to uncertainties in the electron-capture rates, to guide experimental work at NSCL and in the future at the Facility for Rare Isotope Beams (FRIB), and to improve the weak-rate library.

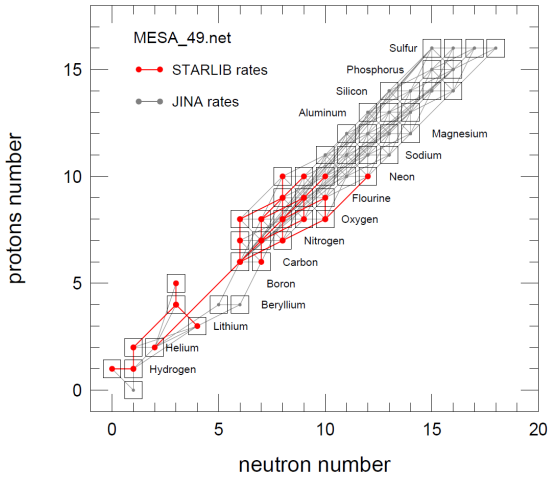
The creation of the weak-rate library and the sensitivity study was performed within the framework of JINA-CEE. Since the simulation of other important astrophysical phenomena, such as thermonuclear supernovae and accreting neutron stars, also require accurate weak reaction rates, the weak-rate library will have strong benefits to the broader astrophysical community.

Details are available in the published work: C. Sullivan et al., *The Sensitivity of Core-Collapse Supernovae to Nuclear Electron Capture.* The Astrophysical Journal, 816, 44 (2015).

New Theory Project @ASU

Contributed by Carl Fields, Arizona State University

Properties of Carbon-Oxygen White Dwarfs From Monte Carlo Stellar Models: In this new project, we explore the final stellar mass, composition, and structure properties as a function of the uncertainties in 26 STARLIB + JINA reaction rates covering hydrogen and helium burning. We focus on the evolution of a 3 Solar Masses star from the pre-main-sequence to the onset of the thermally pulsing AGB phase, and perform the first Monte Carlo reaction rate study using full stellar models. Additionally, we evolve a grid of 1 to 6 Solar masses models with MESA from the pre-main-sequence to the final carbon-oxygen white dwarf using the low, median, and high STARLIB reaction rate distributions.



The 49 isotope nuclear reaction network used in this study

Upcoming JINA-CEE spring events

Electron Capture Supernovae and Super-AGB stars

February 1—5 2016, Melbourne, Australia

Frontiers in Nuclear Astrophysics

March 29 — 31 2016, South Bend, Indiana

Workshop on Experiments for X-ray Burst Nucleosynthesis

May 22 2016, Athens, Ohio

Symposium on Neutron Stars in the Multi-Messenger Era

May 23 — 27 2016, Athens, Ohio

R-Matrix on Methods and Applications

June 27 — July 1 2016, Santa Fe, New Mexico

New Online Seminar on Neutron Stars and Dense Matter

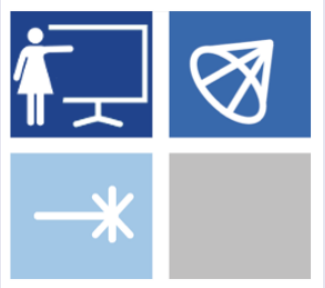
We have a new biweekly online seminar initiated and hosted by our members Sanjay Reddy and Ingo Tews from the University of Washington.

The seminar is meant to help coordinate and initiate research, and help junior people establish collaborations.

It is broadcasted via zoom every second Friday at 2pm EST and everybody who is interested is welcome to join.

Our next seminar with JINA-CEE senior investigator Sean Couch as a speaker will take place this Friday, January 29th. He will talk about "Simulations of Supernovae and Their Massive Star Progenitors in 3D".

Read more on the workshop's website!



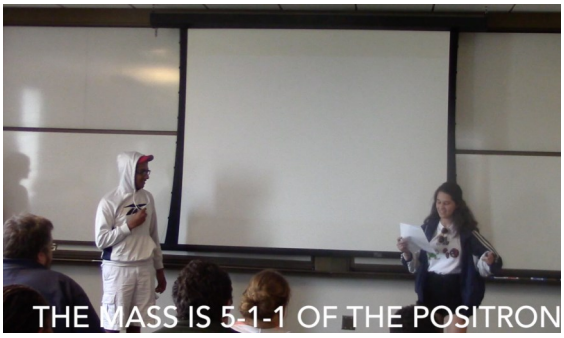
JINA-CEE Outreach

Contributed by Micha Kilburn

JINA-CEE Outreach continues to expand and improve upon successes of JINA Outreach programs. Each year we reach about 5000 people through roughly 50 face-to-face events. However, since nearly all of these events are near Michigan State University or the University of Notre Dame, we continue to increase our web presence so that our outreach and education are as international as our science collaborations.

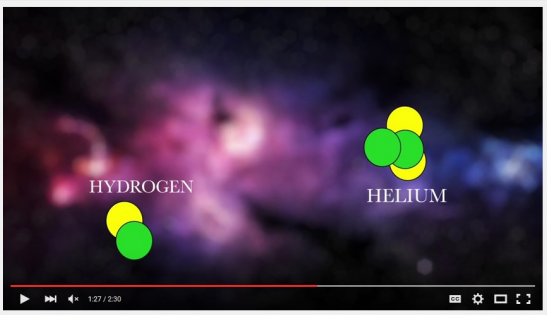
Our facebook page is one of our main doors to the public, especially to advertise local events. Our twitter page attracts a more scientific audience and is being revitalized thanks to Lena. Our YouTube channel includes playlists of our videos about nuclear science, our outreach programs, and even some physics humor. More recently, we've used Google Hangouts to have video calls that are recorded and can be posted to YouTube.

Over the summer, NSF hosted a hangout with JINA-CEE members to highlight the PFC Program. Viewers were able to ask questions through twitter. PAN students at MSU were able to participate and impressed the panel by asking the most scientific questions. PAN students at Notre Dame also had their five minutes of fame. At the end of the program, each group gives a short presentation on their favorite experiment of the week, which were recorded and posted for others to view. They include a rap tribute to the speed of light experiment.



A former PAN teacher invited JINA-CEE researchers to talk to all of the chemistry and astronomy students at his school over the course of a day. The school happened to be in Wisconsin, so we again used Google hangouts as a virtual venue for grad students, post docs, faculty, staff, and the JINA-CEE director himself to tell students about their research in different areas of nuclear astrophysics.

JINA-CEE also produced its first music video this fall, a rap about Vega and the CNO cycle. We worked with professionals from the music and video industry to produce the piece, inspired by former JINA Director, Michael Wiescher, and a dog named Vega.



CNO Rap feat. Vega

Recent Publications

C. Sullivan, E. O'Connor, R.G.T. Zegers, T. Grubb, and S.M. Austin. *The Sensitivity of Core-Collapse Supernovae to Nuclear Electron Capture*. APJ **816**, 44 (2015).

D.W. Bardayan et al. *The first science result with the JENSA gas-jet target: Confirmation and study of a strong subthreshold $^{18}F(p,\alpha)^{15}O$ resonance.* Phys. Lett. B **751**, 311 (2015).

I.U. Roederer et al. *Detailed chemical abundances in NGC 5824: another metal-poor globular cluster with internal heavy element abundance variations.* MNRAS **455**, 2417 (2016).

A. Jerkstrand, S.J. Smartt, and A. Heger. Nebular *spectra of pair-instability supernovae*. MNRAS **455**, 3207 (2016).

S. Jones, C. Ritter, F. Herwig, C. Fryer, M. Pignatari, M. G. Bertolli, and B. Paxton. *H ingestion into He-burning convection zones in super-AGB stellar models as a potential site for intermediate neutron-density nucleosynthesis.* MNRAS **455**, 3848 (2016).

W. Janesh et al. *The SEGUE K Giant Survey. III. Quantifying Galactical Halo Substructure.* APJ **816**, 80 (2016).

JINA-CEE is supported by the National Science Foundation through the Physics Frontier Center Program

Links to our institutions websites:

JINA-CEE Core Institutions:

Michigan State University, Department of Physics and Astronomy, NSCL
University of Notre Dame, Department of Physics, ISNAP
Arizona State University, SESE
University of Washington, INT

JINA-CEE Associated and Participating Institutions:

CCAP Ohio State University, EMMI-GSI Helmholtz Gemeinschaft Germany, Florida State University, INPP Ohio University, Los Alamos National Laboratory / LANSCE-3, McGill University Canada, MoCA Monash University Australia, North Carolina State University, NAVI Germany, NUCLEI LANL, Argonne National Laboratory, Princeton University, Center for Nuclear Astrophysics China, Cluster of Excellence Origin and Structure of the Universe Germany, TRIUMF Canada, University of Chicago, University of Minnesota, University of Sao Paulo Brazil, University of Victoria Canada, Western Michigan University, Ball State University, Hope College, Indiana University South Bend, SUNY Geneso

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